



Optimization in the National Airspace System

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Outline

- Problem description
- Research plan
- Examples



Traffic Flow Management (TFM) Problem

- **Capacity**
 - Theoretical maximum flow rate supported by the separation standard
- **Throughput**
 - Rate of flow realized in operation
- **Efficiency**
 - How close is throughput to capacity?
- **Objective**
 - Maximize flow rate to meet traffic demand

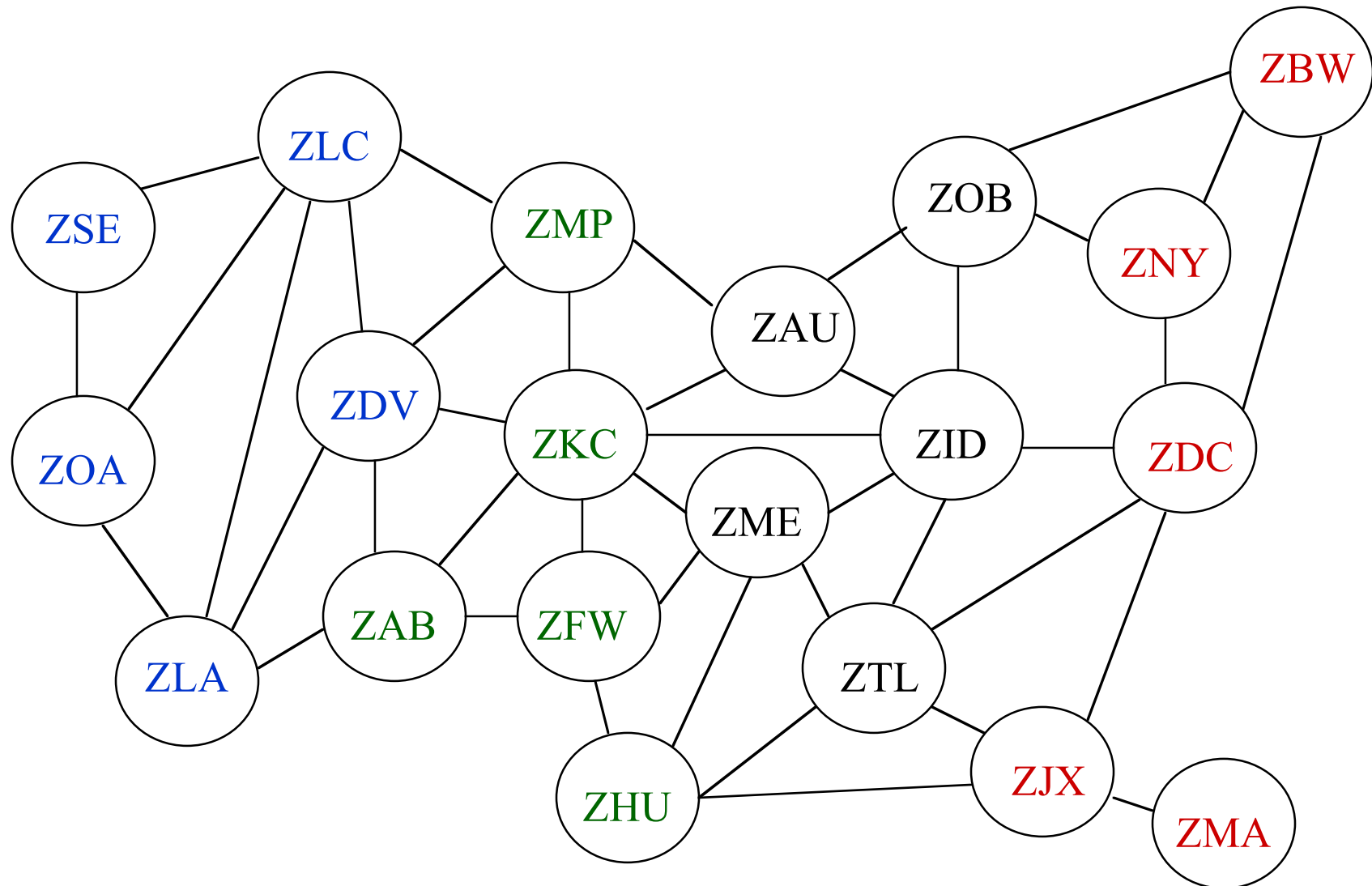


Characteristics of TFM

- **Hierarchical command and control structure**
 - 20 centers and 830 high and low altitude sectors
- **Time scales**
 - 1 to 6 hours (National and Center flow planning)
- **Large number of aircraft (~10,000)**
- **Inter-center boundary connectivity**
- **Sector congestion**
- **Aggregation and decomposition**



Inter-center boundary connectivity





Goal

- **Develop algorithms and optimization software to deal with system-wide TFM optimization issues in both current and future systems**



Research plan

- **Develop algorithms and optimization software to maximize flow rate to meet traffic demand**
 - **Current System**
 - » **Spatio-temporal decomposition**
 - » **Use Playbook or other re-routing schemes**
 - » **Optimize aircraft transit times to minimize delay and meet congestion constraints**
 - » **Automate the process of formulating the optimization problem for different levels of aggregation and decomposition**
 - **Future Systems**
 - » **Optimal en route ATC concept**
- **Develop a scenario database**
- **Co-ordination with other VAMS concept development efforts**
- **Evaluate the results using FACET**



Future ATM Concepts Evaluation Tool (FACET)

- **Simulation tool for exploring advanced ATM concepts**
 - Flexible environment for rapid prototyping of new ATM concepts
 - Interface with Host and ETMS data
 - Can be integrated with other tools of varying complexity and fidelity
- **Balance between fidelity and flexibility**
 - Model airspace operations at U.S. national level (~10,000 aircraft)
 - Modular architecture for flexibility
 - Software written in “C” and “Java” programming languages
 - » Easily adaptable to different computer platforms
 - » Runs on Sun, SGI, PC and Macintosh computers
 - Can be used for both off-line analysis and real-time applications



Example: Current system NO WESTGATES/RBV Playbook Plan

The screenshot displays the Future ATM Concepts Evaluation Tool (FACET) interface. The main window, titled "NO WESTGATES", contains the following text:

NO WESTGATES/RBV

Impacted Resource: N90 WESTGATE departure fixes (ELIOT, PARKE, BIGGY, LANNA and JFK via RBV).

Impacted Flow: ZNY Westbound departures via J60, J64, J80, J6, J48, and J75.

A "Close" button is located below the text.

The bottom of the interface features two panels:

- Future ATM Concepts Evaluation Tool (FACET):** This panel includes a toolbar with icons for animation, simulation, airspace, aircraft, and applications. Below the toolbar, it shows "Status: Waiting", "Number Flying: 0", and "UTC Time:". The main display area is a map of the Eastern United States with green flight paths and labels for airports: IND, CMH, PIT, BWI, and DCA. A "User-Selected Zoom Area" is indicated at the bottom.
- NAS Constraint Setup:** This panel has tabs for "File", "Prefs", and "Display". The "Display" tab is active, showing sub-tabs for "Metering Setup", "GDP Setup", "Delay Stats", "Playbook Setup", and "CDR Selection". Under "Playbook Setup", a list of constraints is shown, with "NO WESTGATES" selected. Below this list, the "Implemented Plans" section shows "NO WESTGATES". At the bottom of this panel are buttons for "Display Graphics", "Cancel Display", "Clear All", "Display Text", "Implement", "Cancel", and "Close".



Impact of Rerouting and Departure Delays on ZNY

| Sector Counts (In) | | | | |
|--------------------|-------|-------|-------|-------|
| File Edit Table | | | | |
| Time | ZNY73 | ZNY42 | ZNY34 | ZNY10 |
| Cap | 16 | 15 | 17 | 17 |
| 13:06 | 8 | 14 | 14 | 14 |
| 13:21 | 14 | 16 | 11 | 17 |
| 13:36 | 16 | 16 | 10 | 18 |
| 13:51 | 6 | 12 | 15 | 13 |
| 14:06 | 11 | 8 | 10 | 14 |
| 14:21 | 12 | 9 | 8 | 10 |
| 14:36 | 9 | 11 | 10 | 12 |
| 14:51 | 7 | 11 | 7 | 16 |

Nominal Sector Counts

| Sector Counts (In) | | | | |
|--------------------|-------|-------|-------|-------|
| File Edit Table | | | | |
| Time | ZNY73 | ZNY42 | ZNY34 | ZNY10 |
| Cap | 16 | 15 | 17 | 17 |
| 13:06 | 7 | 15 | 19 | 9 |
| 13:21 | 9 | 12 | 20 | 12 |
| 13:36 | 14 | 13 | 14 | 15 |
| 13:51 | 6 | 10 | 17 | 10 |
| 14:06 | 11 | 7 | 14 | 11 |
| 14:21 | 12 | 8 | 11 | 9 |
| 14:36 | 7 | 10 | 14 | 9 |
| 14:51 | 7 | 10 | 10 | 13 |

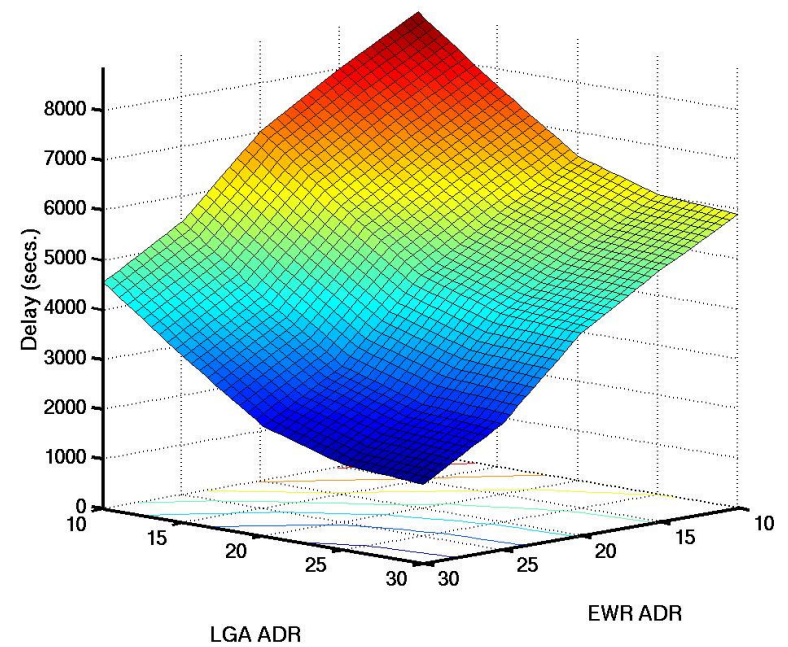
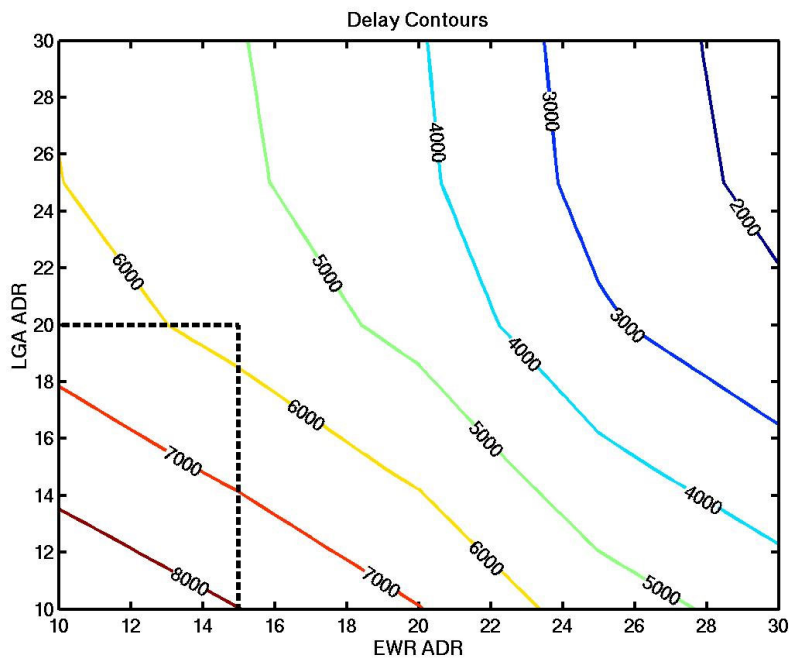
NO_WESTGATES
Rerouting

| Sector Counts (In) | | | | |
|--------------------|-------|-------|-------|-------|
| File Edit Table | | | | |
| Time | ZNY73 | ZNY42 | ZNY34 | ZNY10 |
| Cap | 16 | 15 | 17 | 17 |
| 13:06 | 7 | 13 | 15 | 9 |
| 13:21 | 8 | 10 | 13 | 12 |
| 13:36 | 13 | 13 | 10 | 14 |
| 13:51 | 6 | 7 | 10 | 10 |
| 14:06 | 9 | 5 | 9 | 11 |
| 14:21 | 10 | 8 | 6 | 9 |
| 14:36 | 6 | 10 | 8 | 9 |
| 14:51 | 6 | 9 | 8 | 13 |

NO_WESTGATES +
EWR and LGA Departure
Delays



EWR and LGA Delay Contours



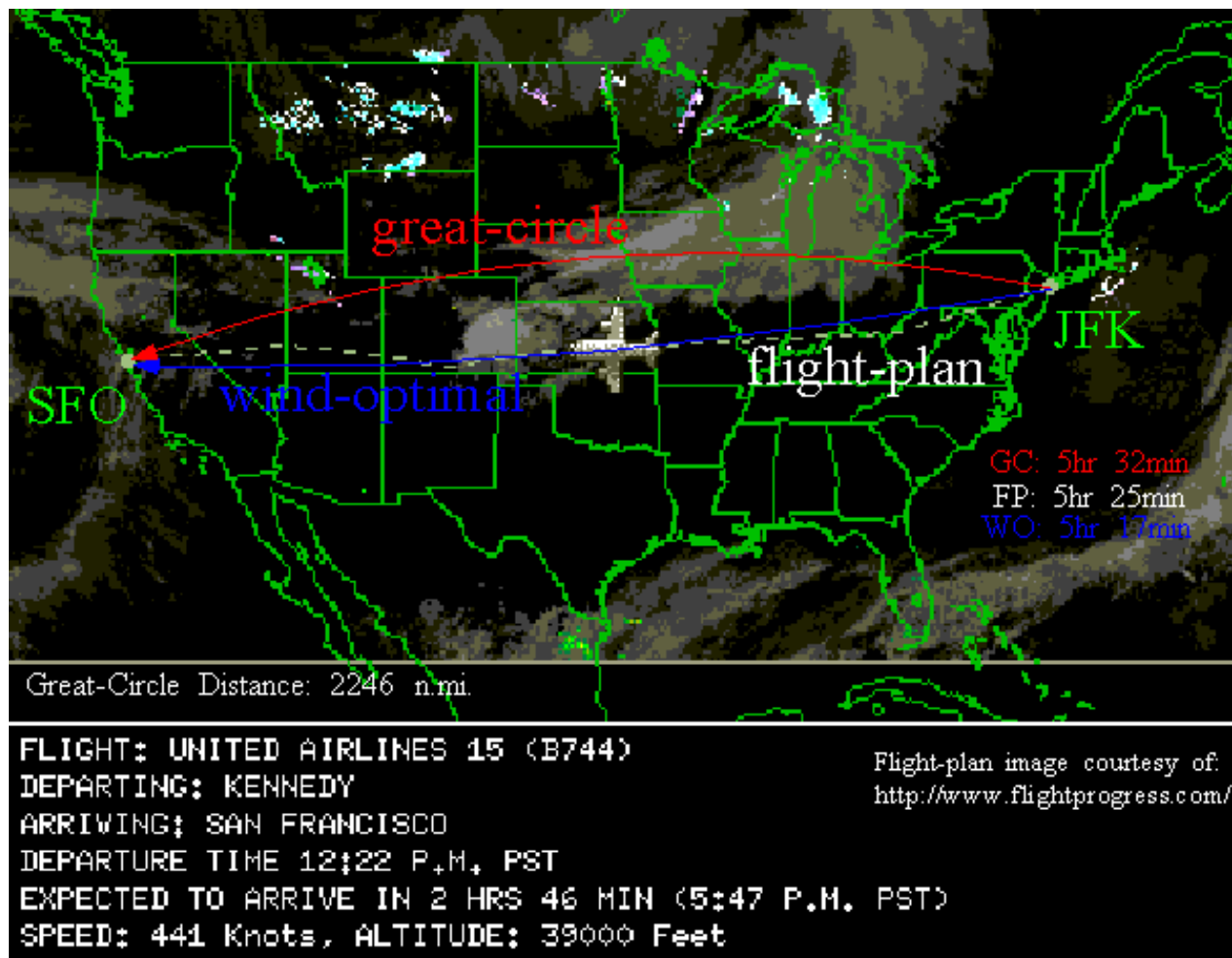


Example: Future system Optimal en route air traffic control

- **Sequential trajectory planning**
- **Wind-optimal routing**
- **Full-trajectory conflict resolution**
- **Periodically re-compute to mitigate disturbances**
- **Incorporate stochastic disturbances (Weather, SUA)**

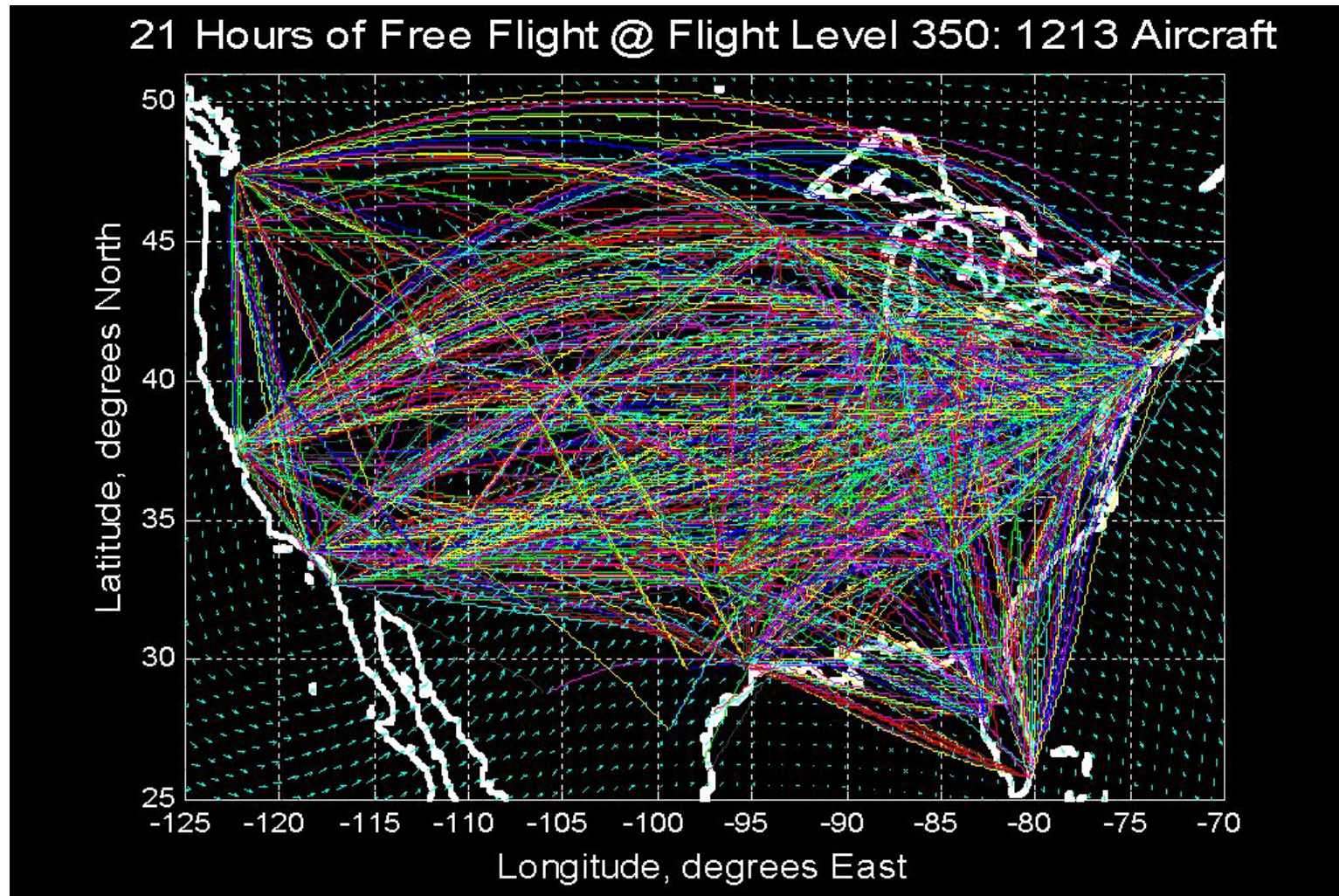


Wind-optimal route





Optimal routes





Optimal ATC video

